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THE ATMOSPHERE OF STELLAR SPACE.

BY G. D. LIVEING, CAMBRIDGE, ENGLAND.

IT was an interesting speculation that Sir R. Ball opened up in this journal, a short time since, with regard to the lunar atmosphere. His argument might easily be carried further, and would take us, as I shall try to show, into the realms of stellar space. It has been objected to his theory that the velocity of the particles of air at ordinary temperatures, though on the average about five hundred yards per second, is not enough to carry a particle so quickly away from the moon that it would not be drawn back again by its gravitation. This objection vanishes if we consider, not the average velocity, but the velocities of individual particles, and the changes those velocities rapidly undergo in consequence of frequent collisions among the particles. It is not easy to grasp the numbers involved in my argument, but I will state them on the authority of Lord Kelvin's popular lecture on the size of atoms. He gives the number of particles in one cubic centimetre, or one-sixteenth of a cubic inch, of atmospheric air at ordinary barometric pressure and at ordinary temperature, as not less than a million million of millions, or 10^{18}. Maxwell, in his article on "Atoms," in the Encyclopædia Britannica, makes the number greater. These particles cannot move far, not more on the average than about one hundredth of a thousandth of a centimetre, without encountering one another, so that each particle collides with one or another of its neighbors no less than five thousand million times in every second. If we suppose the density of the moon's atmosphere to be only a millionth of that of our atmosphere at the earth's surface, there will still be at least a million millions of particles in one cubic centimetre of it, and the frequency of their encounters with each other will still be some thousands per second for each of them. These encounters will cause them to be perpetually changing their velocities, and while some will have, at any given instant, velocities many times greater than the average, others will move at correspondingly slower rates. The directions, also, of their movements will be constantly changing from the same cause. If we suppose two particles, moving with equal velocities in directions at right angles to one another, to come into direct collision, one of them will have its velocity increased in the ratio of the square root of two to one, or rather more than seven to five, while the other will be reduced to momentary rest. If, now, the former come into a similar collision with a third particle, one of these two will acquire a still greater velocity. And considering the prodigious number of the particles and the short distance they can move without encountering others, it is evident that there must be an immense variety of rates of motion amongst them, and many of them must have velocities far exceeding that necessary to carry them clear away from the moon, or the earth, or even from the sun. In fact, amongst so many millions of millions the chance that some one will go on increasing its velocity at every one of a large number of successive encounters is very great indeed, practically a certainty. If this be granted, some, if it be but a small fraction of the whole, will be always escaping from the outer surface of the lunar atmosphere into the planetary space; and the like must go on from the atmospheres of other planets, only the fraction of the whole which get clear away from the bigger planets will be so much less because of the greater attraction of the bigger masses.

One interesting consequence of this escape of only the quicker moving particles, is that the temperature of interplanetary space must be thereby raised above that of the outer regions of a planet's atmosphere. For the temperature is directly proportional to the average square of the velocities of the particles, and as only the quickest fly off for good, the average velocity of the remainder must be less than that of those that break away. The process of dissipating an atmosphere into space might be stopped by its own cooling effect. But it is obvious that there is another cause which prevents anything like this. The planets are continually sweeping through the interplanetary space where the escaped particles are moving about, and even if the density of this interplanetary atmosphere be only a millionth of a millionth of the density of that at the earth's surface, still there will be at least a million particles in each cubic centimetre, and some of them will get swept up by the planets in their course and will not get away again. Hence the process of dissipation will cease when a planet picks up in its course through space just as many as it loses by diffusion in the same time. It follows from this that there must exist in planetary space an atmosphere, greatly reduced in density, it is true, but of the same chemical constitution as the earth's atmosphere. That is to say, the chemical constituents will be the same, though not quite in the same proportions. For the average velocity of the particles of nitrogen is a trifle greater than that of the particles of oxygen, and so the former will escape into space rather more frequently in proportion to their numbers than the latter. Besides, the effect of gravity is to increase very slightly the proportion of oxygen to nitrogen in the lower strata of the atmosphere. Hence, for both reasons, the atmosphere of planetary space will be a trifle richer in nitrogen than the air we breathe. There is so very little free hydrogen in our atmosphere that we cannot detect it, but for all that, it is most probable that there is a very little. And as oxygen particles are sixteen times as heavy as those of hydrogen, the proportion of free hydrogen to the other gases will be proportionally greater in the upper regions of the air than in the lower; and since hydrogen particles move four times as quickly as oxygen particles, it follows that the former will escape from the earth's attraction about four times as fast, and so the proportion of hydrogen in planetary space may be sensibly greater than in air we are able to test. A similar argument will apply to particles of water vapor, which are little more than half as massive as particles of oxygen. If all the planets are thus losing continually some of their atmospheres and picking up an equal amount from the space they move in, it follows that all the planets must have atmospheres of similar constitution to our own. For each planet has for ages been losing some of its own and acquiring some of the air